Phase Retrieval from the Coherent GISAXS Measurements

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Coherent X-ray Diffractive Imaging (CXDI) is a new and fast developing field of lenseless x-ray microscopy. It has a potential to reach diffraction limited nanometer resolution at least for non-biological samples. Applications of this method to the study of nano-systems will be given in this talk. One of the well established methods to provide information on the shape and the size of the quantum structures is a Grazing Incidence Small Angle X-ray Scattering (GISAXS) technique. However results of this method are based on a delicate fitting procedure when a complicated models of x-ray scattering and different type of correlation functions are used to obtain reasonable fit to experimentally measured data. Here we propose to use coherent x-rays in GISAXS geometry in order to get all structural information about the sample in a model independent way by phase retrieval of scattered intensity.

Recently we studied theoretically [1] the image formation and reconstruction of coherently illuminated islands of nano-size dimensions in GISAXS geometry. In this scattering geometry the 1-st Born approximation (kinematic scattering) fails to describe correctly the scattering process and instead Distorted Wave Born Approximation (DWBA) has to be used. As a consequence there is no simple relationship between the scattered amplitude and the electron density of the sample in the form of Fourier transform. Total amplitude in DWBA is a coherent sum of several scattered amplitudes. It means that iterative phase retrieval technique that is based on application of Fourier transform many times to reconstruct the phase will fail to give correct image of the sample. However it was demonstrated that there are some favorable conditions (with incident angle close to the critical angle) when GISAXS diffraction pattern originating from individual island of nano-size dimensions can be inverted using iterative phase retrieval technique and can give a reliable image of the island shape. It was also shown that due to interference effects reconstructed image contains superposition of two images: island itself and a standing wave formed by interference of two scattered waves.

These theoretical ideas were tested in our experiments performed at BW4 station at HASYLAB [2] and ID01 beamline at ESRF. GISAXS diffraction patterns were measured from SiGe quantum dots grown on a (001) surface of Si by the Liquide Phase Epitaxy technique. All islands have narrow size distribution, same orientation and are randomly distributed on the surface. Different size of the islands was probed with the Coherent GISAXS technique: 50 nm, 140 nm, 200 nm and 1000 nm. First results of reconstruction from the measured data show all predictions revealed by theoretical analysis.

[1] I.A. Vartanyants, D. Grigoriev, A.V. Zozulya, Thin Solid Films (2007) (to be published).
[2] I.A. Vartanyants, et al., HASYLAB Annual Reports 2006, Part I, p. 253 (2006).